Tracking PMD from Fiber to Cable

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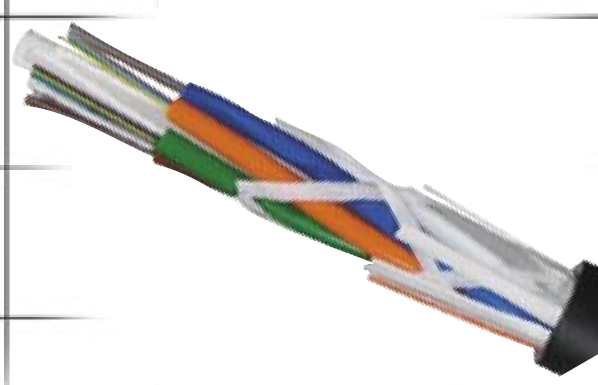

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Most customers use optical fiber in cabled form and under installed conditions, not on fiber spools. To alleviate concerns about polarization mode dispersion in field-installed optical fiber, OFS recommends using fiber with low PMD that also maintains its high quality when cabled and installed.

Introduction

Most end-users believe that polarization mode dispersion (PMD) performance has improved to the point that it is only an issue for high-speed and long-haul systems. Recent data shows that fibers, previously measured to have low PMD may in fact have high enough PMD once installed that will restrict 10 Gb/s transmission over relatively short distances.[1] H. Haunstein of Lucent Technologies Inc. has indicated in published literature that operating at high channel bit rates (10 Gbit/s and more), PMD, especially on old fiber routes, is a limiting factor for system performance.[2] In addition, J. Nikolopoulos, of Corvis Corporation writes that key concerns facing carriers today center on understanding and deploying effective network strategies for optical link chromatic dispersion (CD) and PMD compensation.[3] It was not too long ago that Annie Lindstrom of Telephony wrote that according to Dana Cooperson of RHK, Verizon Communications and SBC Communications believe that 60% to 70% of their fiber will not cost-effectively support OC-192 systems due to high PMD and other issues.[4]

There has been an enormous amount of engineering effort dedicated to eliminating or controlling PMD in optical fiber since it was discovered over twenty years ago. PMD has still proven difficult to meaningfully specify and customers are not clear about all the parameters that affect PMD in the network. The difficulty arises from the statistical nature of PMD; vague or irrelevant fiber specs; inappropriate test methods; the use of "typical values" rather than established requirements; measuring PMD on spooled-fiber instead of in cable-like conditions and ignoring temperature effects.

As such, it is very important to have both high quality control on parameters that affect fiber PMD; fiber process capabilities that can both improve and stabilize PMD; and a cable process that maintains low PMD performance. Knowing what to expect with regards to PMD performance in cable will prevent network outages (seen as either random or persistent burst errors, signal fading or full blown link downtime).

PMD is sensitive to changes in the environment (such as temperature, humidity or vibration) after deployment, so it is essential that the customers have an understanding of what contributes to PMD and how to minimize it.

PMD Causes and Mitigation

Most of the causes of PMD in optical fiber are well known and understood. PMD is related to the creation of birefringence in the optical fiber. Simply put, the "single mode" of the "single mode fiber" is made up of two modes associated with the two principle angles of polarization in the fiber. Without birefringence, the separate polarizations would travel in unison and hence look like a single mode. But with birefringence, one will travel faster than the other and cause pulse spreading or dispersion of the optical mode because of its polarization (i.e., PMD).

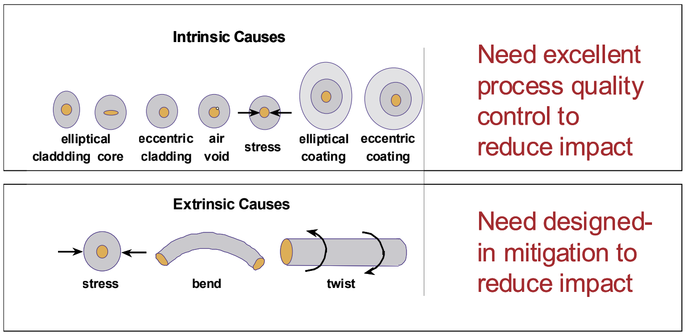


Figure 1. The causes of birefringence leading to PMD in optical fibers can be internal or external in origin

Figure 1 shows the many ways that the birefringence that gives rise to PMD can be created. Some causes are internal to the optical fiber such as asymmetries, including non-circular or non-concentric fiber geometry, residual non-uniform stress, coating defects, cabling induced pressure, or small airlines in the glass. To minimize these impacts, the vendor has to maintain high quality control throughout the manufacturing process from raw materials to drawn fiber.

Other causes are external such as bends, twists or stress. The external causes are also usually very time dependent, especially when the fiber is cabled and deployed in a network. Here, the fiber is subjected to time varying stresses due to temperature changes, barometric pressure changes or mechanical vibrations (like trucks or trains passing nearby), making it difficult to easily compensate for it. The best way to alleviate this cause of PMD is to design-in a process to mitigate it. OFS was the first manufacturer to patent[1] and implement a process that mitigates and stabilizes the PMD of their optical fibers. This process is used today throughout the OFS product line of optical fiber, including our award

Cabled Fiber PMD

Low spool PMD is not a good indicator of PMD in installed form. Many fiber manufacturers indicate that the PMD of their fiber may change when cabled without specifying how it changes. OFS has developed a screening process that determines that OFS' fiber PMD predominately decreases when measured off of the spool, as indicated in Figure 2a, whereas other manufacturers' fiber PMD may rise significantly when removed from the spool (Figure 2b). Such a measurement configuration is indicated in IEC standards.[1] Note that the scales are not the same in this figure and that the OFS fiber begins with spooled PMD below 0.1 ps/km$^{1/2}$ that drops to lower levels. These results indicate that OFS' fiber will produce an extremely low link design value (LDV). In other words, the worst case PMD for the long link (as represented by the LDV) will be much lower for OFS fibers than that of the other manufacturer's indicated in Figure 2b.

These differences in LDV outlined above are confirmed by cable PMD results.

Figure 3 is a result of cabling optical fiber from different manufacturers in the same cable type on the same manufacturing line. All fibers were measured at well below 0.2 ps/km½ on spool before cabling and thus, thought to represent optical fiber with acceptable PMD. However, only the OFS optical fiber maintained its excellent PMD into cabled form.

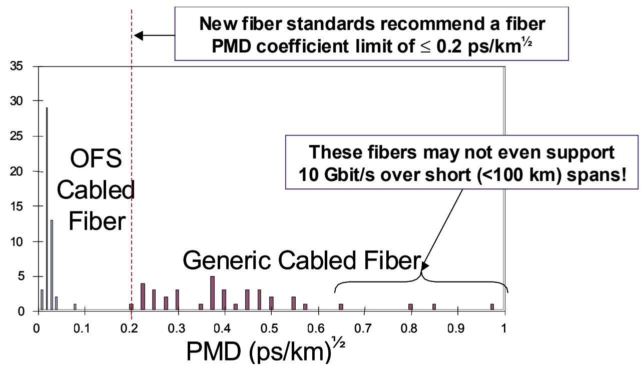
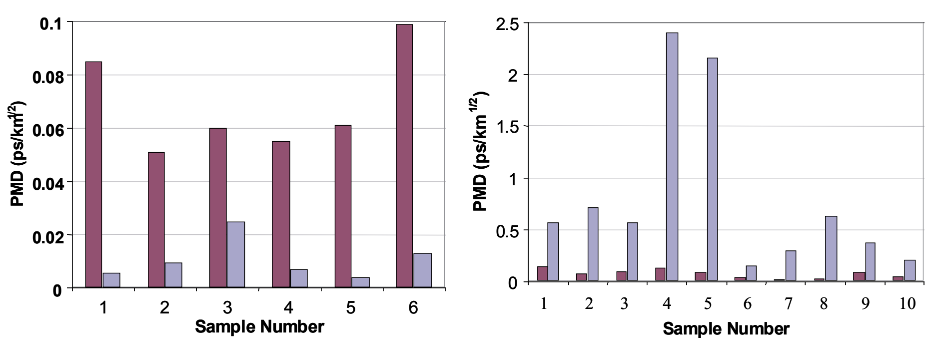


Figure 3. Comparison of PMD of cabled optical fiber measured in a standard, off-reel condition on a flat surface for fiber from different manufacturers that initially measured well below 0.2 ps/km½ on their shipping spools.



(a) (b)

Figure 2. Measurements of fiber PMD on spool (red bars) and off spool in standard low mode coupling configuration (blue bars) for (a) OFS Fibers showing a decrease in PMD when off spool and (b) other manufacturers showing significant increases in PMD when off spool.

Note the scale for (a) is much lower than for (b).

Summary

In purchasing fibers/cables, OFS recommends that customers ask the right questions to ensure that PMD performance in cable supports the claims in the manufacturers' specifications. PMD is a fiber parameter that can't be ignored. To minimize the impact of PMD in the network, customers should ensure that the manufacturer has a high quality, mapped process from fiber manufacturing to cable production.

[1] A. Judy, et al., "Fiber PMD – Room for Improvement," NFOEC 2003.
[2] H. Haunstein, Lucent Technologies Inc., OFC 2001, WT4.
[3] J. Nikolopoulos, Corvis Corperation, NFOEC 2002.
[4] A. Lindstrom, "Defeating Dispersion," Telephony, Nov. 27, 2000.
[5] Hart-Fuff-Walker, U.S. Patent 52980047, March 29, 1994
[6] IEC 60793-48, Section 5.2.1.

For additional information please contact your sales representative. You can also visit our website at http://www.ofsoptics.com or call 1-888-fiberhelp.

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